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FINAL REPORT.

One of the goals of the STRAT mission was to improve our understanding of transport in the stratosphere. We have used our coupled 2-D model to analyse transport between the tropics and midlatitudes using aircraft measurements of {CO2} and {N2O} made during the SPADE and ASHOE/MAESA campaigns (Boering et al. 1994) for model validation. We have further used the model to estimate errors in the experimental determination of the age of stratospheric air that arise from nonlinear increases of real tracers such as {CO2} and {SF6}. The interpretation of measurements made during STRAT is still in progress.

Most of the work performed under this contract has been described in the second year progress report, submitted in April of 1996. In the following, the research is summarized and some additional work that has become relevant in the meantime is described.

We have developed an interactive model of the dynamics, chemistry and radiation of the stratosphere with partial support from this contract. The dynamics module integrates the primitive equations on a sphere. Lower boundary zonal winds and eddy geopotential heights are specified from observations. Chemistry and tracer transport are done in two dimensions. The chemistry model is a family model. Long lived species are transported and short lived species are determined in intervals of 5 to 10 days by assuming photochemical steady state. Full diurnal integrations with the fast species are performed periodically and diurnal coefficients, derived from the explicit integration are used to determine the steady state solution. Heating rates in the stratosphere are calculated from model ozone and the model temperatures and circulation fields are used in the chemistry transport module.

Due to the use of the primitive equations, the characteristics of transport in the tropics are somewhat different in our model than in many other 2-D models. For example, our model generates a circulation associated with the Quasi-biennial Oscillation (QBO) which is asymmetric about the equator and naturally explains the observed asymmetries in the QBO ozone signal in the subtropics (Jones et al., submitted to JGR.)

In order to make sure that our model generated circulation is reasonable, we compared long lived tracers in the model with data obtained by instruments aboard UARS and ATLAS. These data are most useful at altitudes over 25 km. They show distinct gradients in mixing ratios across the subtropics. These features have been interpreted in a conceptual 'pipe model' by Plumb (1996). We assumed a reduced mixing in the tropics. Negligible diffusive transport between the tropics and midlatitudes means that the burden of simulating the tropical regime and the mass exchange to midlatitudes is on the residual circulation with is interactively calculated in our model. We were able to achieve good agreement with the satellite data with a minimum of tuning.

For the {CO2}/{N2O} correlations, we specified the {CO2} surface mixing ratios from 1980 to 1994 at the model lower boundary (about 1 km equivalent pressure altitude). The data were obtained from T. Conway at the NOAA CMDL. Correlations of long lived tracers with similar source regions are normally not good tests for the transport as the tracers have to stay proportional to each other regardless of the flow field. In this case, however, {CO2} has source variations on a seasonal timescale and an annual trend whereas {N2O} increases only very slowly (about .5 ppt/year) at the surface. The slope of the correlation curves changes with season and the annual increase of {CO2} is clearly evident at lower values of {N2O}.

Our model is able to reproduce the measured correlations fairly well. The seasonal behaviour of the model correlations is in good agreement with the data. A sensitivity analysis showed that a threshold value of Kyy is required in the Southern Hemisphere to reproduce the ASHOE/MAESA data. The value is about 1/3 to 1/2 of the Northern Hemisphere seasonal average in agreement with Holton et al. (1996). The advective transport in the lower stratosphere is not able to get the seasonal signal of {CO2} to midlatitudes where it was measured. Rapid diffusive transport in Winter is required to reproduce the measurements. We further found that the correlations are sensitive to the lower boundary treatment (i.e. model tropopause) and to dissipative processes within the tropics. Changing the extratropical forcing of the circulation by doubling/halfing Kyy, for example, does not affect the correlations. In this case, the overturning rates change by +/- 20 percent, the change in the circulation pattern in the tropics and subtropics does, however, affect {CO_2} and {N_2O} in the same manner. Therefore, these data do allow us to rule out some circulation patterns in the lower stratosphere and help to indentify model problems but they do not allow us to constrain the strength of the circulation to better than about 30%.

Mean ages of stratospheric air, when determined from {SF_6} or {CO_2} measurements are subject to some uncertainties because both of these tracers do not increase exactly linearly in time. The errors associated with the nonlinearly increasing surface boundary can be estimated in the model if age is determined as a tracer with a stratospheric source (Boering et al., 1997) and as a lag time of model calculated stratospheric tracer values to tropospheric tracer concentrations. The errors in the lower stratosphere are estimated to be about one half to three quarter years. Doubling {Kyy} in the model as described above changes the true age of stratospheric air by a similar amount. Therefore, we have the same problem as we have with the {CO_2}/{N_2O} correlations in reducing the uncertainty in overturning rates. The data for age don't seem accurate enough.

Differences in computed age between various models seem to be much larger than the differences we obtain for different wave forcing of the circulation. This statement is based on preliminary results from the NASA Models and Measurements Intercomparison Workshop II in which we are currently participating. Our model age agrees fairly well with the age derived from {SF_6} measurements. We plan to use more of the tropical STRAT data to validate our age calculations.

References:

Boering, K. A., B. C. Daube Jr., S. C. Wofsy, M. Loewenstein, J. R. Podolske, and E. R. Keim:

Tracer-tracer relationships and lower stratospheric dynamics: {CO2} and {N2O} correlations during SPADE. Geophys. Res. Lett., 21, 2567-2570, 1994

Boering, K. A., S. C. Wofsy, B. C. Daube, H. R. Schneider, M. Loewenstein, J. R. Podolske, T. J. Conway: Stratospheric mean ages and transport rates from observations of carbon dioxide and nitrous oxide. *Science, 274,* 1340-1343, 1996

Holton, J. R., P. H. Haynes, M. E. McIntyre, A. R. Douglass, R. B. Rood and L. Pfister: Stratosphere-Troposphere exchange. Rev. Geophys., 1996

Plumb, R. A.: A 'tropical pipe model' of stratospheric transport. J. Geophys. Res., 101, 3957-3972, 1996

Jones, D. B. A., H. R. Schneider, and M. B. McElroy: Effects of the Quasi-Biennial Oscillation on the zonally averaged transport of tracers, submitted to *J. Geophys. Res.*, 1997